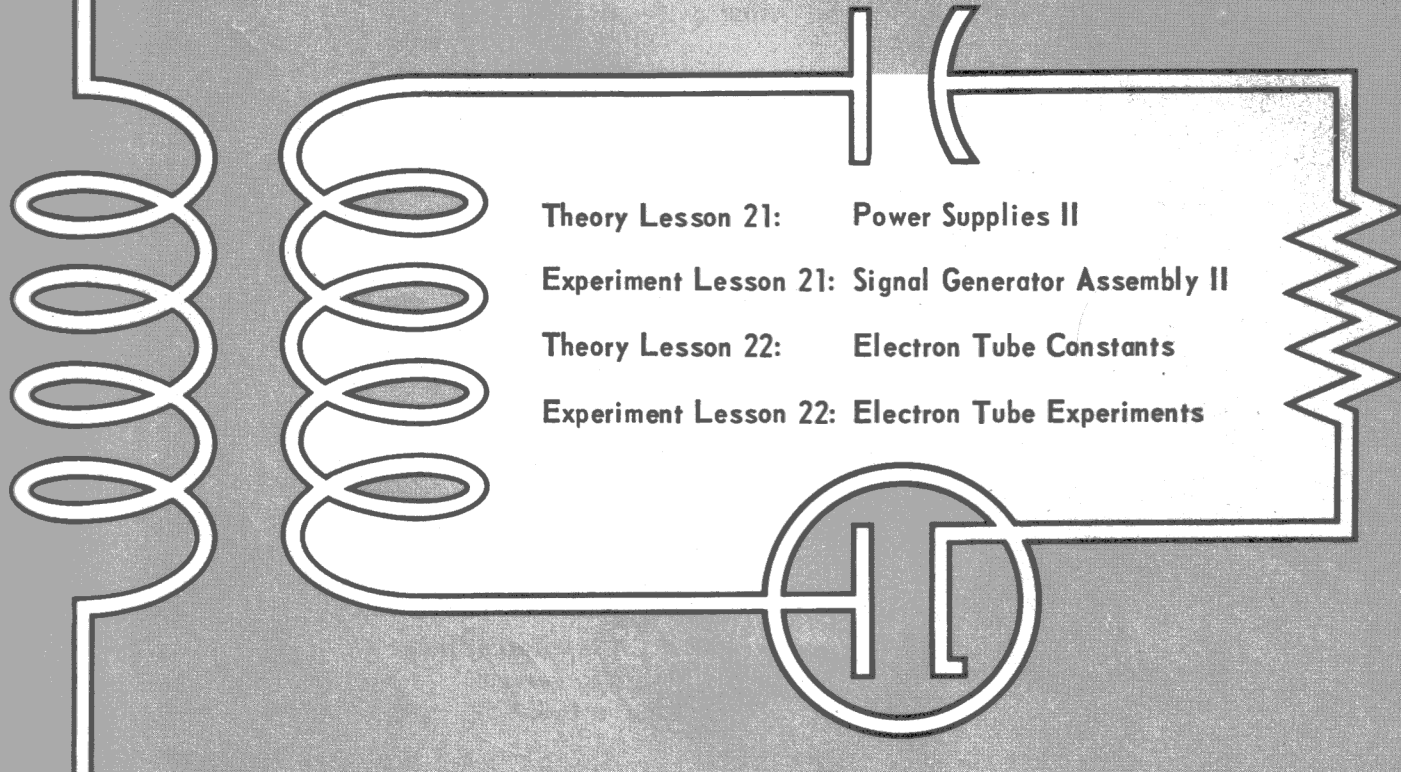


ELECTRONIC FUNDAMENTALS



Theory Lesson 21: Power Supplies II
Experiment Lesson 21: Signal Generator Assembly II
Theory Lesson 22: Electron Tube Constants
Experiment Lesson 22: Electron Tube Experiments



RCA INSTITUTES, INC.

A SERVICE OF RADIO CORPORATION OF AMERICA
New York, N. Y.

ELECTRONIC FUNDAMENTALS

THEORY LESSON 21

POWER SUPPLIES II

- 21-1. Special Power-Supply Circuits
- 21-2. Voltage Regulation
- 21-3. Voltage Multipliers
- 21-4. Automobile Power Supplies
- 21-5. Power Converters and Generators



RCA INSTITUTES, INC.
A SERVICE OF RADIO CORPORATION OF AMERICA
HOME STUDY SCHOOL
350 West 4th Street, New York 14, N. Y.

Theory Lesson 21

INTRODUCTION

In the last lesson, we discussed standard power-supply systems — those that you will meet most often in your career as a radio and television serviceman. This lesson tells you about special power-supply circuits and special power-supply systems that you should know about. In some cases, you are told how particular power-supply circuits are put together and how they work. In other cases, you are told about power-supply equipment that may be obtained from your radio-parts dealer, which, for one reason or another, you should not try to design and make yourself. Other, more specialized, power-supply circuits are discussed in later lessons when the equipment in which they are used is taken up. So, even this lesson will not be the last word on power supplies — there will be more to come.

21-1. SPECIAL POWER-SUPPLY CIRCUITS

Heater Circuits. In the last lesson, we discussed simple filament and heater cir-

cuits: series-connected heaters that all draw the same current, and parallel heaters (or filaments) that operate on the same voltage but may draw unequal currents. Here, we discuss several special filament and heater problems and show how they are solved. Naturally, all possible heater or filament problems cannot be discussed here. However, the methods used in solving the following problems will guide you in solving others.

Let's suppose that a radio comes into your shop for repair that has the tube lineup shown in Fig. 21-1a, and that the output tube (25L6) is burned out. For some reason or other, you can't get a 25L6 or 25L6-GT to replace the burned out tube and you would like to use a 35L6-GT in its place. After looking in the tube manual, you find that the 25L6 and all of the original tubes in the series string draw 0.3 ampere of current; while the 35L6-GT draws only 0.15 ampere. You can't let 0.3 ampere flow through the 35L6-GT without having it burn out too. The problem is partly solved by placing a resistor in shunt with the 35L6-GT to carry

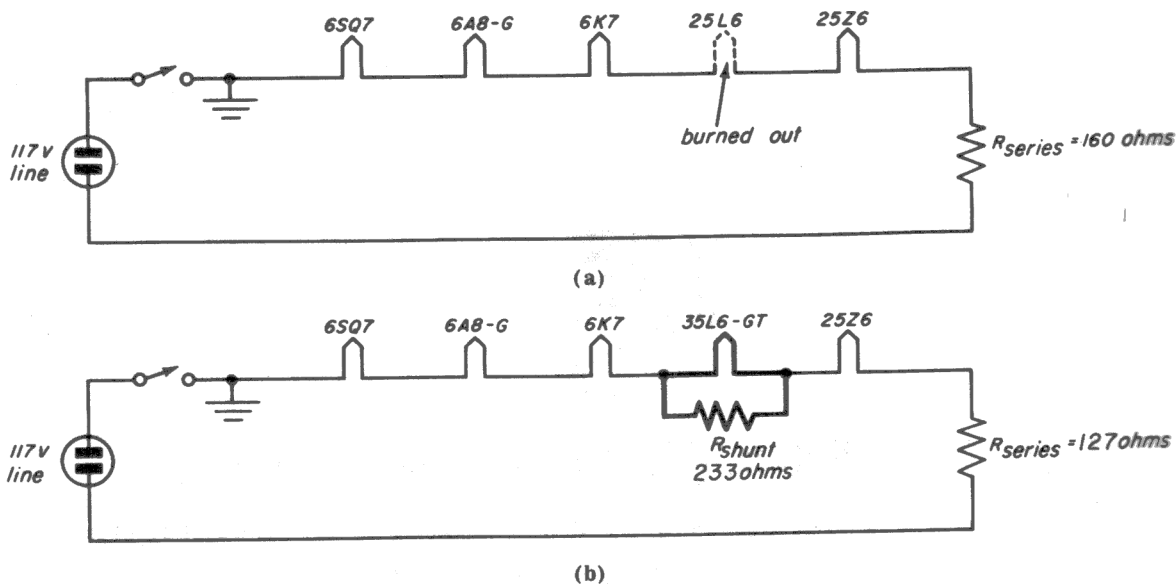


Fig. 21-1

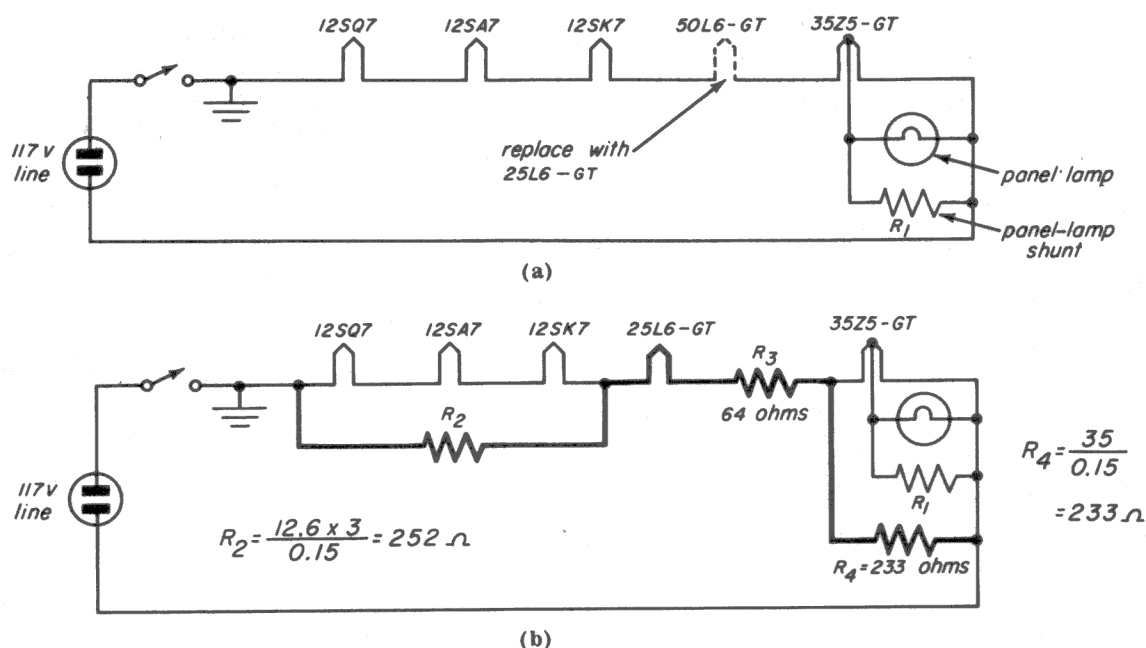


Fig. 21-2

the extra 0.15 ampere that the tube cannot safely carry (Fig. 21-1b). The voltage across the resistor (35 volts) divided by the current (0.15 amp) gives a resistance value of 233 ohms. The new tube and its shunt resistor produce a voltage drop of 35 volts instead of the 25 volts of the 25L6. So, the value of the series dropping resistor (R series) becomes 127 ohms instead of 160 ohms. There are other differences in operating characteristics between the two tubes, but they have little effect on the set's operation.

Suppose it were necessary to replace a 50L6-GT with a 25L6-GT in a circuit where all the other tubes draw 0.15 ampere, as in Fig. 21-2a. The 25L6-GT draws 0.15 ampere more than the other tubes. This added current must not flow through any of the other heaters, so shunt resistors R_2 and R_4 (Fig. 21-2b) are shunted across the 12.6-volt tubes and the 35-volt rectifier. In addition, a resistor is placed in series with the heater string to drop the voltage 25 volts (the difference between 50L6-GT and 25L6-GT heater voltages). The series-dropping resistor is placed between the 25L6-GT and 35Z5-GT heaters because the rectifier plate is connected to the rectifier heater tap. If R_3 were placed between the 35Z5-GT and the line, the rectifier plate supply voltage would be too low.

Filament Circuits. In three-way portables and some battery receivers, tube filaments are connected in series, as in Fig. 21-3a. The first four filaments each take 1.4 volts while the fifth filament is center-tapped and requires 2.8 volts. The current needed to heat the filaments is 0.05 ampere. With this much current flowing through each filament, the voltage drop across each of the first four filaments is 1.4 volts, while the tapped filament has a drop of 2.8 volts. However, plate and screen currents flow through each filament in addition to the heating current. The total plate and screen current of the receiver may be about 12 ma, of which the greater amount is due to the output tube. In the circuit shown in Fig. 21-3a, all of this current must flow from B-(ground) through the filament string. This means that each filament carries, in addition to its heating current, the plate and screen currents of the tube or tubes that are nearer to the positive end of the filament string than itself. For example, the filament nearest ground carries 50 ma of heating current plus the total B current (12 ma), making a total of 62 ma. This is more current than the filament is supposed to carry and may cause it to burn out. If the plate and screen current of the output tube is carried directly from ground through a resistor R as in Fig. 21-3b, most of B+ current will be shunted around the other four tubes and their filaments will not be overloaded.

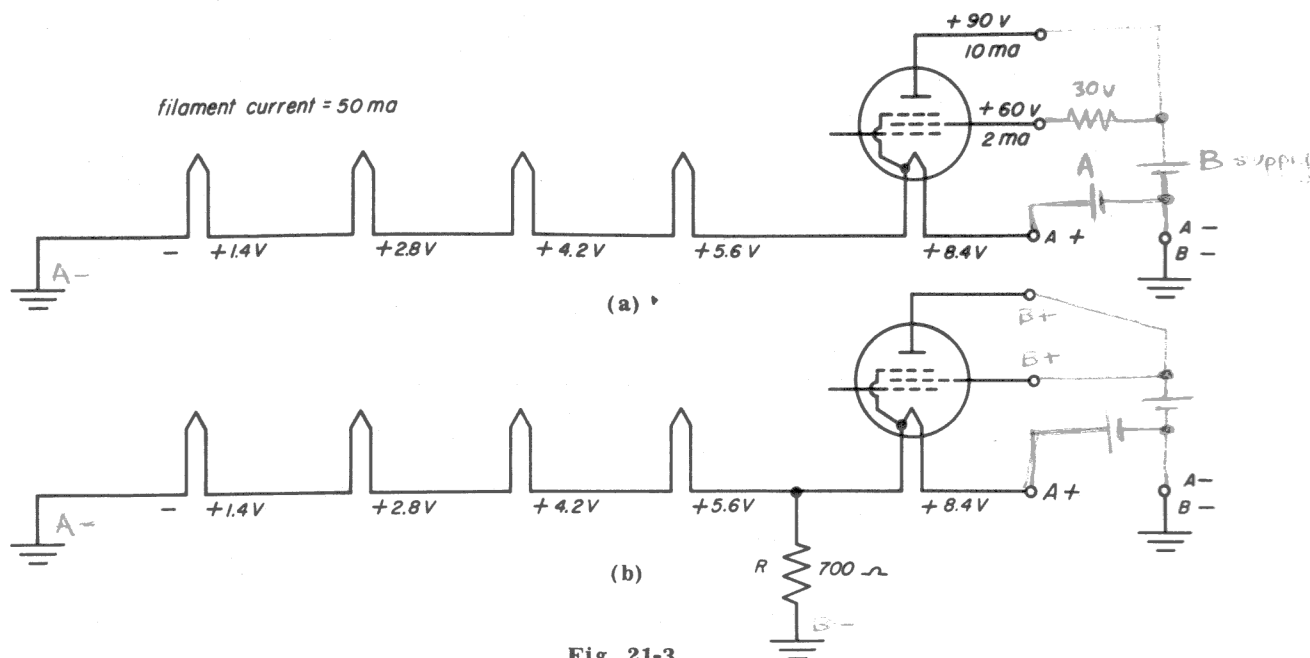


Fig. 21-3

We can find the value of resistance needed by using Ohm's law. Let's assume that the total screen and plate current of the output tube is 8 ma; the voltage drop between the points of connection is 5.6 volts so:

$$R = \frac{5.6}{0.008} = 700 \text{ ohms}$$

When such a filament string is connected for power-line operation in a three-way portable, the filament voltage is supplied through a dropping resistor from the d-c output of the rectifier. Look at Fig. 21-4. In the drawing, R_1 is a current-limiting resistor; R_2 is part of the RC filters; R_3 is a series voltage-dropping resistor; R_4 conducts the output tube's plate and screen currents from ground.

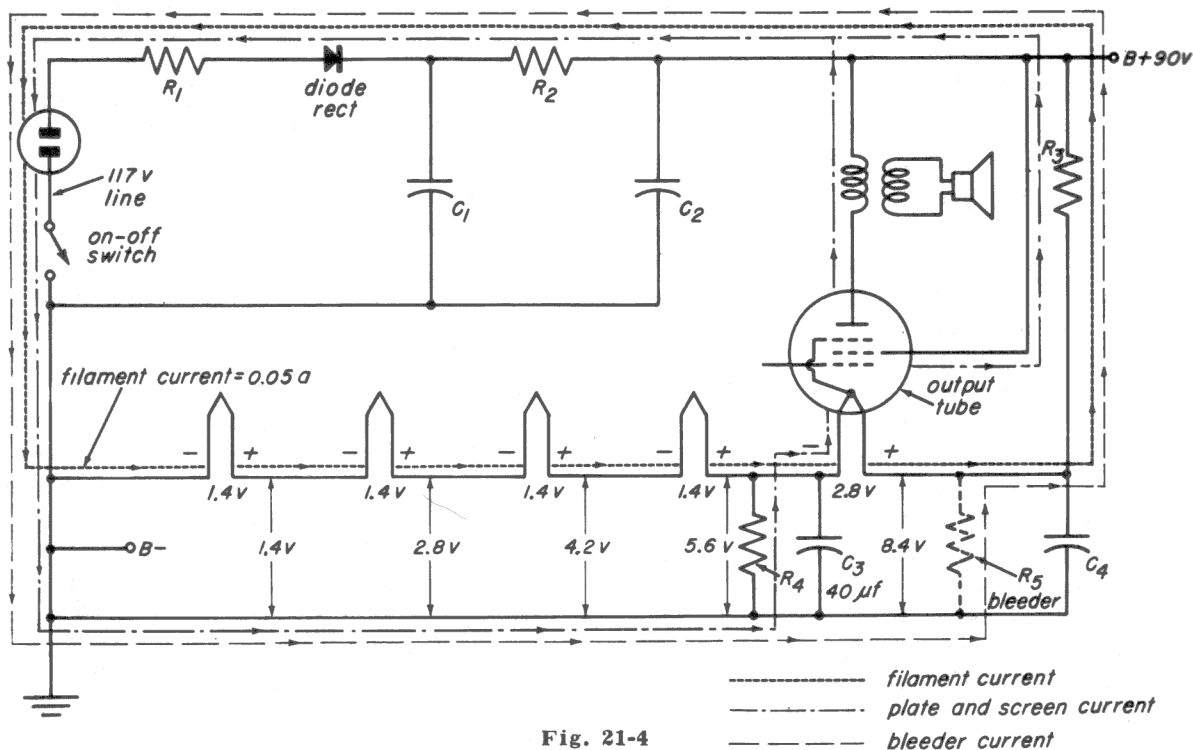


Fig. 21-4

Let's see why this circuit is not safe. If one of the first four tubes were to burn out, the filament circuit would open up. Then current flow through R_3 would decrease considerably. As a result, there would be a smaller voltage drop across R_3 and the capacitor C_4 would charge up almost to the value of the $B+$ voltage. If the defective tube were then replaced by a good one, the filament circuit would then be complete once more. But the filament voltage across the first four tubes would be almost 90 volts, and the discharge current of the capacitor C_4 would be so great that one or more of the tubes would burn out and open up the filament circuit once more. If the charge on the capacitor bleeds off through a bleeder resistor R_5 , the charge will not become high enough to burn out the tube filaments. However, to play safe, never remove a tube from a three-way receiver while the set is on; and never replace a blown tube in such a receiver until you first check to see that the on-off switch is in the off position. Five milliamperes of bleeder current is all that is necessary in the circuit shown.

$B+$ Filter Circuits. Most of the radio receivers made during the 1930's used electro-dynamic speakers. Such speakers used electromagnets instead of permanent magnets.

The resistance of the magnetic field coil of typical electro-dynamic speakers was from about 400 ohms to 3,000 ohms. The speaker field of an a-c or a-c/d-c receiver was often used in place of a filter choke, as in Fig. 21-5a. In an a-c/d-c receiver, the resistance of the a-c/d-c field was about 400 ohms and in an a-c receiver ranged from 1,000 to 2,000 ohms, when used as a choke. In some a-c/d-c receivers, the speaker field has a resistance of between 2,500 to 3,000 ohms. In such cases, the field was not used as a choke because the resistance was too high, but was connected to one diode of a twin-diode rectifier, such as the 25Z5 or the 25Z6-GT. As shown in Fig. 21-5b, the field was connected between one of the cathodes and the B -ground.

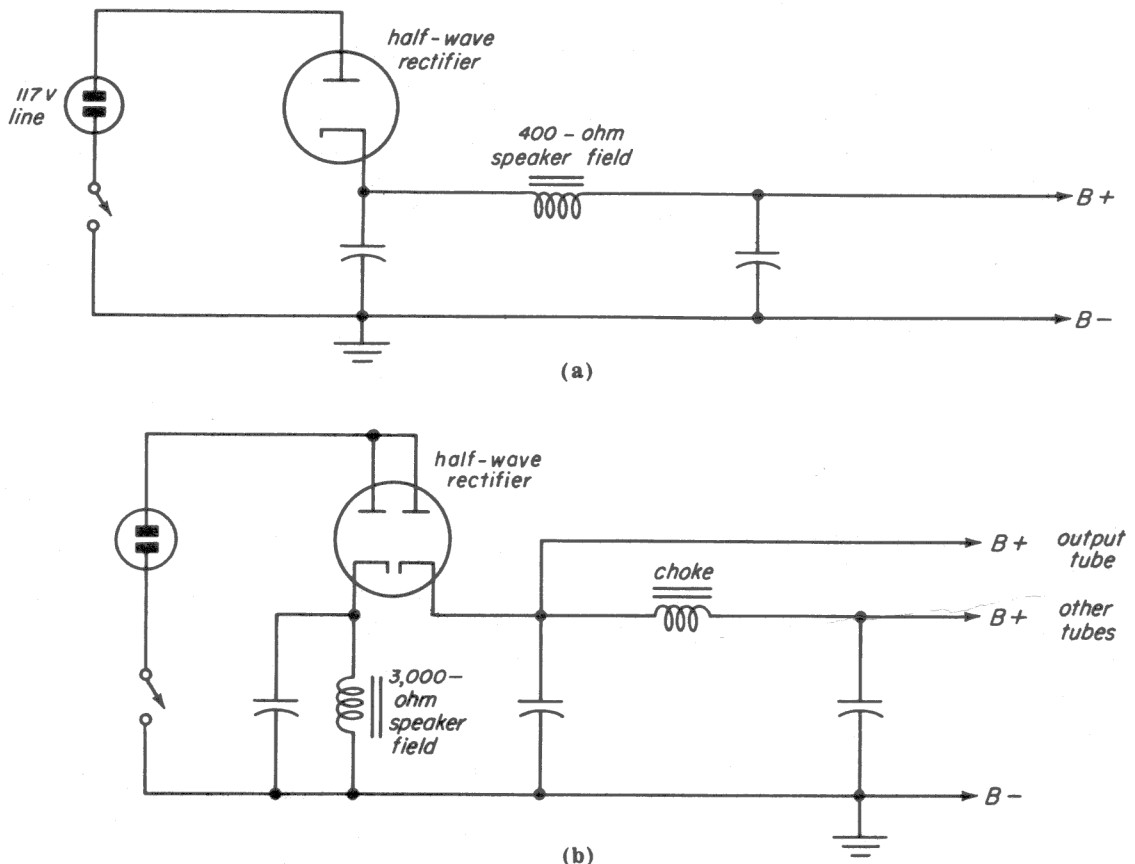


Fig. 21-5

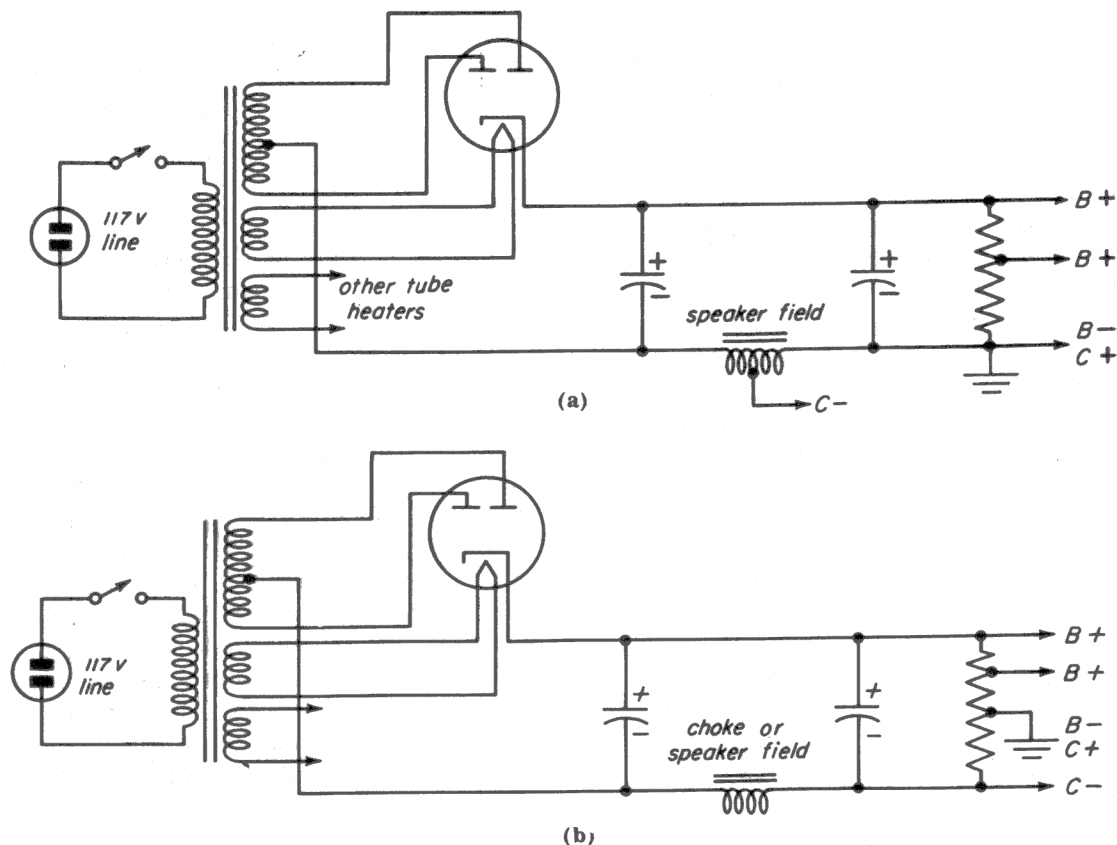


Fig. 21-6

Notice that the $B+$ supply for the output tube is taken directly from the input to the filter. This is done sometimes when the voltage at the output of the filter is too low for the proper operation of the tube. The ripple voltage of this $B+$ is not amplified in the final stage and does not cause objectionable hum in the speaker output.

Speaker Field or Filter Choke In Negative Leg. Until now we have discussed power supply filtering where the filter choke was connected in the positive leg (side) and where the input and output filter capacitors had a common connection to ground. While this is the more popular filter connection, it is possible to place the choke or field coil at the negative end of the power supply, as shown in Fig. 21-6a. In this case, the speaker field may have a resistance of about 1,500 to 2,000 ohms. When the field is tapped, as shown in the schematic drawing, the tap provides a negative C bias for operating one or more tubes of the receiver being supplied with power. However, it is not necessary to use a tapped speaker field or choke to provide bias, because that may be obtained

from the voltage divider, as shown in Fig. 21-6b. Notice that each schematic drawing shows that the positive lead of each filter capacitor is tied to a common point. However, the negative lead of the input capacitor is connected to one side of the speaker field and the negative lead of the output capacitor is tied to the other side of the field. So, a dual capacitor may be used, but it must have separate negative leads or lugs, and may have a common positive lead or lug. If a dual capacitor with common ground lug is used, and connected backwards, one or more of the filter sections will be destroyed. In calculating the voltage needed for either supply, the same method is used as when the choke or speaker field is placed in the positive leg, because no matter in which leg it appears, the choke or speaker field offers the same resistance and has the same voltage drop across it.

High-Voltage Power Supply. Sometimes a source is needed that can supply B power of 1,000-volts or more. For example, a typical cathode ray oscilloscope may require from 1,000 to 3,000 volts of $B+$ power. In most

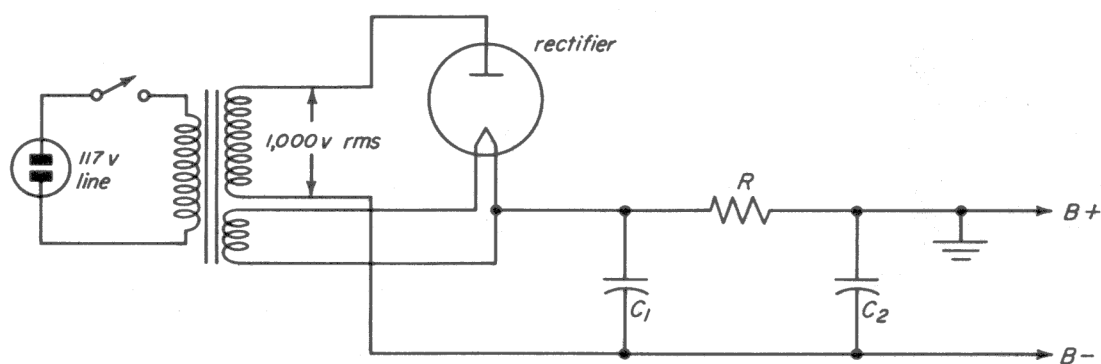


Fig. 21-7

cases, the current drain on a high-voltage supply is very small, ranging from 1 or 2 milliamperes up to 10 milliamperes. For this reason, a half-wave rectifier will supply our needs. Usually, a high-voltage power supply is combined with a normal low-voltage power supply, such as those we have discussed in this and other lessons. The high-voltage winding and the rectifier heater-voltage winding may be part of the transformer, used for the low-voltage power supply or, in the case of Fig. 21-7, it may use a separate power supply. In choosing the rectifier for such a power supply, it is important to remember that the peak inverse voltage of the rectifier you select must be rated at 1.41 or more times the rms voltage of the high-voltage secondary. Another point to remember is that in selecting the capacitors for the input and output filters, be sure that they can handle the rectified d-c voltage, which, in the case of the circuit shown, is around 1,400 volts and calls for capacitors rated

at from 2,000 to 2,500 working volts d.c. Because of the low current flowing, the filter resistor or choke may have a high resistance or reactance value. For example, a resistance of 50,000 ohms might be used in a circuit where only a few milliamperes is flowing. With such high resistance, the capacity of C_1 and C_2 may be about 0.05 to 0.1 microfarad. In wiring a high-voltage power supply, it is important that high voltage leads should not have sharp bends and that they be well insulated. Otherwise, the high voltage is likely to arc across to ground or some nearby low-voltage circuit. In some circuits, the B+, instead of B-, is tied to ground to prevent accidental shock. Later, when you study cathode-ray oscilloscope and television circuits, you will receive complete information about the power supplies used in each type of equipment.

Bridge-Type Power Supply. The schematic diagram in Fig. 21-8 shows a bridge-

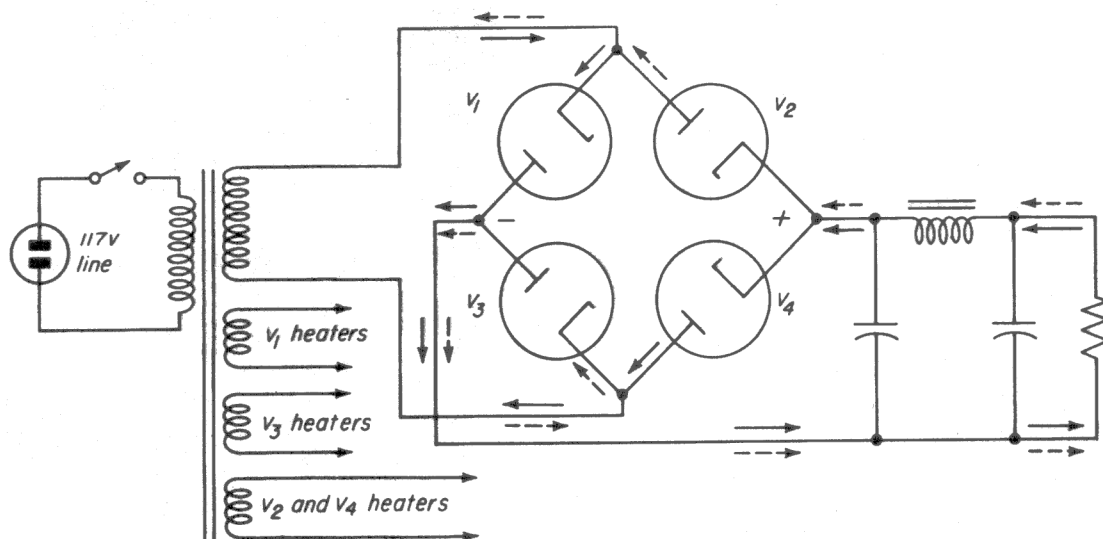


Fig. 21-8

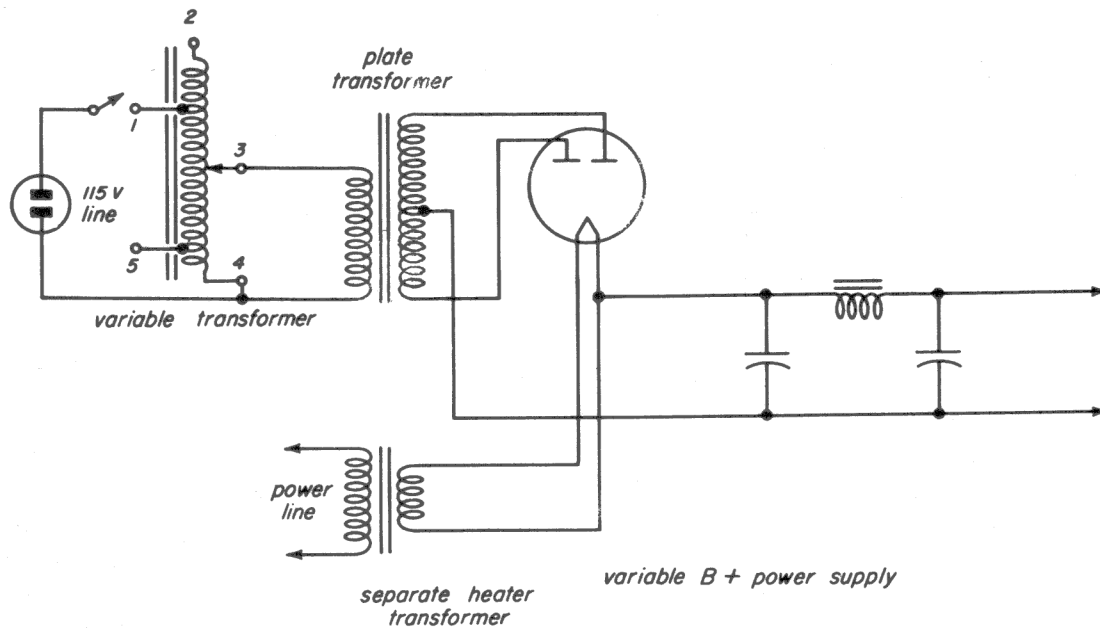


Fig. 21-9

type power supply. A bridge type rectifier is used with a power transformer that has a high voltage secondary, no center tap being necessary. Such a circuit uses both alternations of the sine-wave a-c high voltage so that full-wave rectification results. The use of three separate windings is desirable if indirectly heated rectifiers are used to reduce the possibility of cathode-to-heater breakdown. If directly heated rectifiers are used, the use of three windings becomes necessary, otherwise the single winding will short out the bridge rectifier circuit. An advantage of the circuit is that each rectifier tube may have one-half the peak inverse voltage that would be required, if a full-wave rectifier circuit were used. Instead of using tube rectifiers, selenium or other dry-disc rectifiers may be used.

Variable B+ Power Supplies. In laboratories and some service shops, it is sometimes desirable to have a variable power supply that provides B power in any value from zero to 300 or 400 volts. Such a power supply is shown in Fig. 21-9. The main feature of this power supply is an auto transformer, which is listed in the parts catalog as a *variable transformer*. The one shown in Fig. 21-10 is designed for 115-volt a-c power line. When the power line is connected across terminals 1 and 4 of the vari-

able transformer shown, a-c voltage of any value from zero to 135 volts may be obtained across terminals 3 and 4, as you can see in the schematic drawing (Fig. 21-9) and in the picture (Fig. 21-10). Terminal 3 is connected to a sliding arm, which, when moved by turning the control knob at the top, makes contact, one at a time, with the exposed surface of each turn of the transformer wind-



Fig. 21-10

ing. So the primary of the plate transformer may be supplied with any voltage from zero to 135 volts and the step-up high-voltage secondary voltage may vary from zero to 300 or 400 volts rms, depending upon the transformer chosen. Note that the rectifier is heated by a separate heater transformer. If it were fed by the same primary winding of the plate transformer, the heater voltage, too, would vary from zero to some amount a little higher than the normal heater voltage, which means that the rectifier cathode would be heated properly only when the primary voltage was from 110 to 120 volts in value.

The variable transformer need not be connected permanently to such a variable $B+$ power supply but may be used to supply the primary of a receiver under test with a normal operating line voltage (in areas where the line voltage is under or above normal) or to raise the line voltage to a point where some receiver part that is causing fading or some intermittent trouble breaks down and can be detected.

21-2. VOLTAGE REGULATION

In any of the power supplies that we have discussed in this and other lessons, the output voltage decreases as the load increases. In fact, even if the load remains constant, the output voltage supplied to the load is less than the output voltage when there is no load. The difference between the full-load voltage and the no-load voltage is called the *voltage regulation* of the power supply. It is found by using this formula:

$$\text{Percent of regulation} = \frac{100 (E_1 - E_2)}{E_2}$$

where:

E_1 = the output voltage of the filter without a load

E_2 = the output voltage of the filter with a load

The smaller the percentage of regulation, the better is the regulation.

When the supply voltage or the current drawn by the load remains constant or nearly

so, the regulation of a power supply is not very important. But when changes in signal voltage produce large changes in load current, or where the a-c line voltage varies a lot, regulation becomes important. Then one or more of the methods that we will now discuss should be used to improve regulation.

Choke-Input Filtering. As a result of the work that you did in Experiment Lesson 18, you may have noticed that the voltage output of a choke-input filter varied less with a change in load than did that of a capacitor-input filter with the same change in load. Because the output of a choke-input filter does not vary as much as that of a capacitor-input filter with changes in load, choke-input filters are often used to improve voltage regulation. A choke-input filter is usually required to prevent high-current peaks when using a mercury-vapor rectifier. The regulation of such a combination is very good.

Swinging Choke. Sometimes a *swinging choke* is used to provide good regulation. A swinging choke differs from the standard filter choke in this way — its inductance varies with load. The inductance is high when the load current is low and is low when the load current is high. To understand the theory of a swinging choke, we must first review some of the things we know about the standard low-frequency filter choke. We know that a low-frequency choke is a coil of wire wound on an iron core made from E- and I-shaped laminations. We know that the iron core is used to increase the magnetic field of the coil for a certain current flow over that which the choke would have with the same current flow if it had an air core. We know that the number of lines of force increases as the current flowing through the core increases. However, a point is reached at which a further increase in current produces no additional lines of force, or produces so few more lines of force for the amount of added current that it doesn't pay. This point is called *saturation*. To prevent standard filter chokes from saturating, an *air-gap* is placed in the magnetic circuit of the choke. The air-gap is small and usually consists of a thin layer of paper, fiber, or cardboard inserted between the E- and I-shaped laminated sections of the core. A swinging choke has either a very small air-gap or none at all, so that

the core may be easily saturated. As the core approaches saturation, the inductance decreases.

Of course, the decrease or increase of inductance has no effect on the d-c resistance of the choke, so each increase in load current produces an increase in the voltage drop across even a swinging choke. However, as the inductance of the choke decreases, the voltage input to the choke-input filter increases. So, any increase in voltage drop across the choke is made up for by an increase in the d-c input to the choke, so the output d-c voltage tends to remain constant.

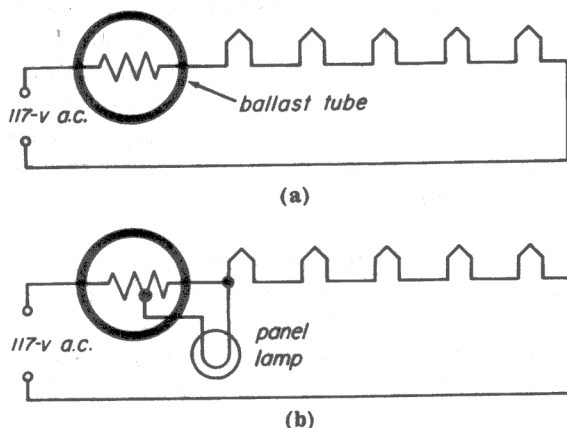


Fig. 21-11

Ballast Tubes. In older receivers, the sum of the voltages of all the series connected heaters was often less than the line voltage. As you have seen, this difference in voltage was taken up by a series filament dropping resistor. By using a special form of resistor, the current change through the filaments due to line voltage changes could be minimized. This resistor, called a *ballast resistor*, is made with fine iron wire, whose resistance increases rapidly with a rise in temperature. Because it operates at red heat, the fine iron wire is usually enclosed in a hydrogen filled tube to prevent burning up.

The ballast tube or resistor was designed to resemble an ordinary electron tube, and to plug into a tube socket. Thus, if it burned out, it could be replaced as easily as any other tube. Some ballast tubes have a tap so that a panel lamp may be shunted across a part of the resistor. The number appearing on the ballast tube identifies it in terms of resistance and base connections.

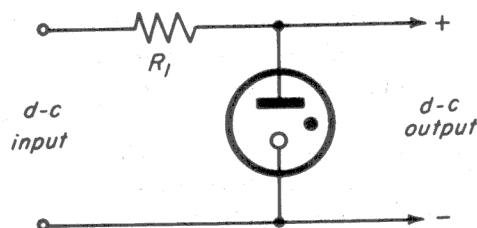


Fig. 21-12

With the ballast resistor in the filament circuit, an increase in line voltage tended to raise the current in the circuit. But this would raise the temperature of the ballast, increase its resistance, and tend to maintain the current constant. Such ballast tubes are rarely used in modern receivers.

Voltage-Regulator Tubes. Another method of regulating the output voltage of a power supply makes use of a gas-tube voltage regulator. A basic regulator circuit is shown in Fig. 21-12. The gas tube or *glow tube*, as it is often called, works on the principle that the voltage across it remains almost the same for wide variations of the current flowing through it. Glow tubes in practical regulated power-supply circuits will hold the d-c output voltage constant within very few volts provided certain conditions are met. These are:

1. The filtered d.c. that appears across the cathode and plate of the glow tube must first reach the value of potential necessary to cause the gas in the tube to ionize before the tube can conduct. This, you remember from Lesson 17, is called the ionization potential, or firing point. Table A shows the ionization voltage for each of the four glow tubes most often used.
2. The current flowing through the tube must not fall below the minimum shown in the table, which is 5 ma for each tube. Otherwise, the tube will stop conducting and there will be no regulation.
3. The current flowing through the tube must not exceed the maximum amount shown for each tube, which is 30 ma for the OB3 and 40 ma for the others. If the current is allowed to exceed the rated value, the glow tube may be damaged. The series resistor R_1 shown in Fig. 21-12 should be selected so that the current flowing through the glow tube will not exceed the rated value when the load is disconnected. The

TABLE A

Rating	OA3/VR75	OB3/VR90	OC3/VR105	OD3/VR150
Approximate ionization potential	105	125	133	185
Minimum operating current (ma)	5	5	5	5
Maximum operating current (ma)	40	30	40	40
Approximate operating voltage (volts)	75	90	105	150
Regulation (volts)	6.5	6	4	5.5

value of resistance may be found by using the following formula:

$$R = \frac{E_1 - E_2}{I}$$

where:

R = resistance in ohms

E_1 = d-c input voltage to resistor

E_2 = voltage rating of glow tube

I = maximum current rating of tube

The voltage rating of each tube is determined by the gas used in it. Table A shows that the operating voltage of the OA3/VR75 is 75 volts, that of the OB3/VR90 is 90 volts, and so on. Operating under normal conditions,

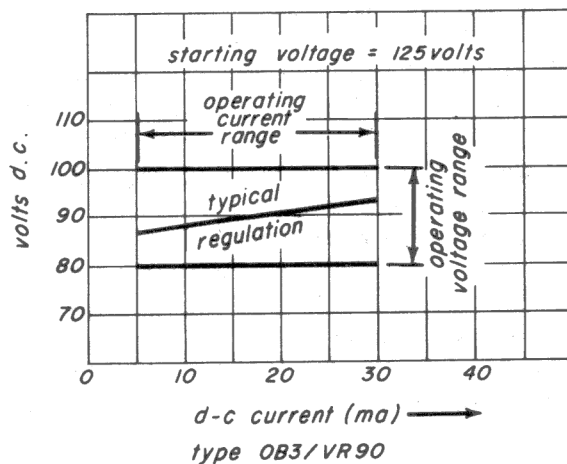


Fig. 21-13

each tube will maintain its rated voltage level within the number of volts shown. For example, the OB3/VR90 has an operating potential of 90 volts with a regulation of 6 volts. This means that the operating voltage for a particular OB3/VR90 tube is around 90 volts. It may be a few volts above or below this figure, and the variation in voltage due to changes in load will be 6 volts or less. The regulation is apt to improve as the tube ages. Typical operating characteristics for an OB3/VR90 are shown in Fig. 21-13.

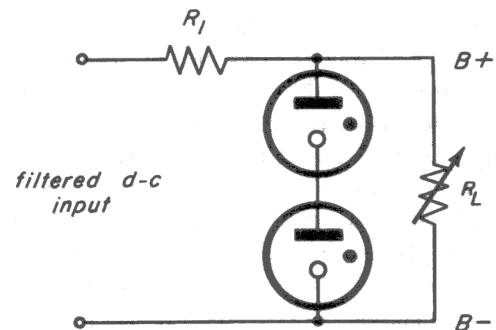


Fig. 21-14

When higher d-c operating voltages are required than those shown in Table A, two or more tubes may be connected in series (Fig. 21-14). For example, if 180 volts of regulated d.c. is needed, two OB3/VR90 tubes connected in series will supply this amount. Normally, a single OB3/VR90 has a firing point that is about 35 volts higher than its operating voltage. It is not necessary to double this amount and add it to the 180 volts to provide two of these tubes with the proper firing potential. A voltage of about

215 volts should prove high enough for the firing potential.

It is possible to connect two unlike glow tubes in series to get a particular value of regulated d.c. For example, an OB3/VR90 and OD3/VR150 may be connected in series to provide 240 volts of regulated d.c. However, the maximum current that may flow in the series is determined by the tube with the lower maximum current: the OB3/VR90. So only 30 ma may flow through the tubes.

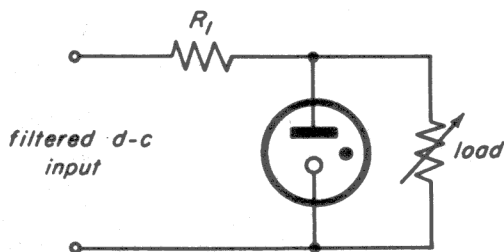


Fig. 21-15

In regulating voltage, the glow tube acts as follows: As the voltage fed by the filter to R_1 (Fig. 21-15) rises, the voltage at the glow tube rises and causes more of the gas to ionize, which increases the glow-tube current. This in turn, causes an increase in the IR drop across R_1 , which brings the $B+$ output voltage fed the load to about the same value that it was before the increase in voltage from the filter. When the voltage drops due to an increase in load current or a change in the d.c. supplied by the filter, the current flowing through the tube drops because fewer gas molecules are ionized. This drop in glow-tube current decreases the IR drop through R_1 and its output $B+$ voltage rises to about the value that existed before the rise in load current. In this way, the glow tube compensates for changes in load current and supply voltage.

Figure 21-16 shows the tube-socket connections to a typical glow tube. Notice that there is a jumper load between pins 3 and 7. This makes it possible to connect the a-c line voltage to the power transformer through the jumper, so that the circuit is broken when the tube is removed from the socket. In this way, it is impossible for the load to receive unregulated $B+$ voltage should the tube be removed from its socket for some purpose or other.

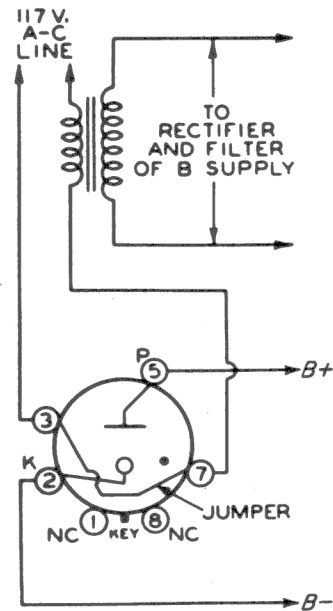


Fig. 21-16

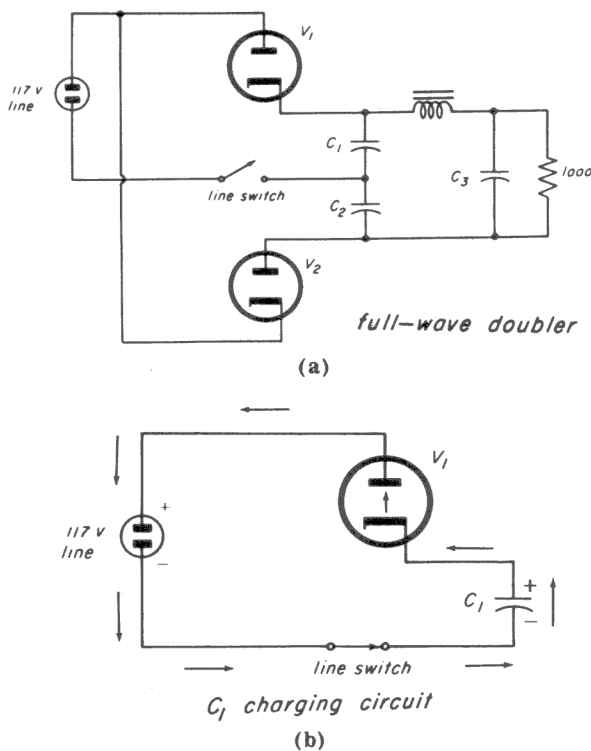
Other voltage regulation circuits are found in electronic equipment. These circuits will be taken up in later lessons when such equipment is discussed.

21-3. VOLTAGE MULTIPLIERS

There are circuits that provide us with the voltage-stepup effect of a transformer without our going to the expense of using a transformer. Such circuits are called *voltage multipliers* because with them we can get two, three, four, or more times the $B+$ voltage that we can get out of the normal a-c/d-c supply. Voltage multiplier circuits operate on a.c. only. The most often used voltage multipliers are those called *voltage doublers*. Let's see how they work.

Full-Wave Doubler. Voltage doublers are divided into two main classes: full-wave doublers and half-wave doublers. A typical full-wave doubler is shown in Fig. 21-17a. The rectified and filtered d-c output of such a doubler varies from about 180 to 250 volts, depending upon the load. At first glance, it may not seem reasonable that this should be so. However, the action of the circuit is not hard to understand once we see how the charges on C_1 and C_2 add to each other.

To begin, let's see how C_1 is charged. Figure 21-17b shows the condition when the



a-c power line cycle makes the plate of V_1 positive with respect to the cathode. During this half cycle the tube conducts and the charging current for C_1 flows as indicated by the arrows. During the second half cycle, V_1 does not conduct and the charge on C_1 starts to leak off through the load. In the meantime, the plate of V_2 is positive with respect to its cathode and the tube conducts, charging C_2 . Figure 21-17c shows the path of the charging current. When the power line cycle again causes V_1 to conduct, the capacitor C_1 will have lost some part of its charge. However, the amount that is lost depends on the time constant of C_1 and its discharge circuit. If the capacity is high enough (20 to 40 μf) and the load is not too great, very little of the charge will be lost. As a result, the voltage of C_1 adds to that of C_2 to produce a total that is about twice the voltage of a single diode and capacitor

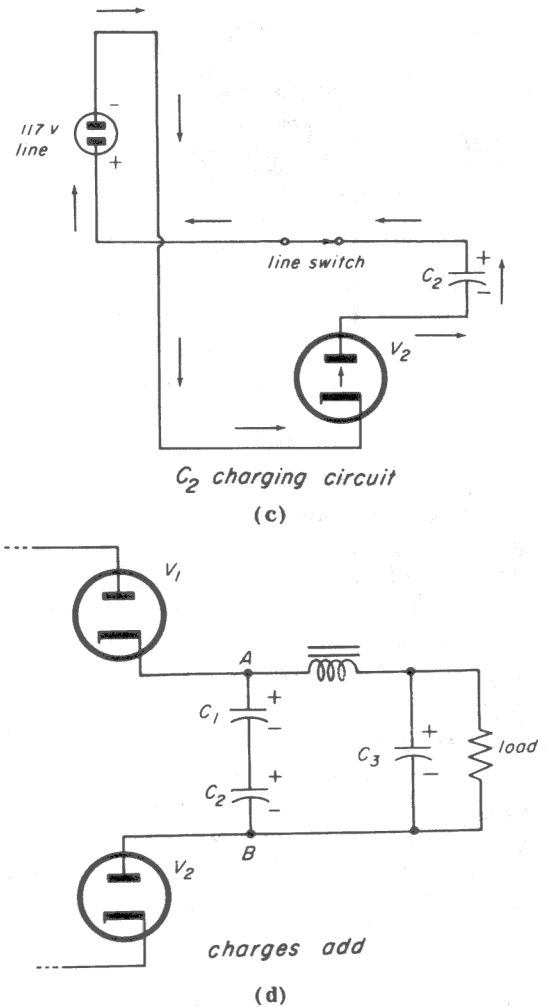


Fig. 21-17

(Fig. 21-17d). The voltage across C_3 therefore is equal to the sum of the two voltages, less the drop through the filter choke. In choosing C_3 , it is important that a capacitor with a voltage rating of sufficient value be selected. The ripple frequency of this circuit is just twice that of the power-line frequency, and the voltage regulation is poor.

Half-Wave Doubler. Another doubler circuit is the *half-wave doubler*, shown in Fig. 21-18a. To understand this circuit, we must

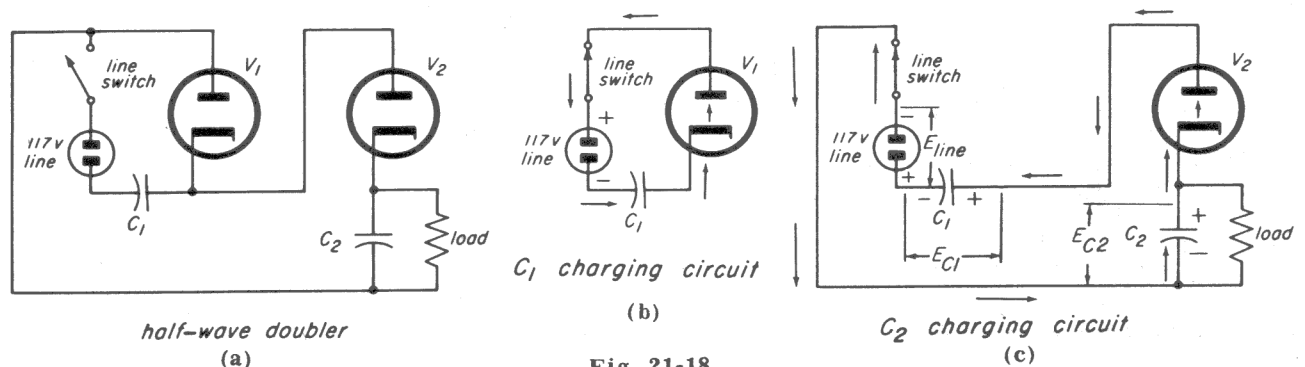


Fig. 21-18

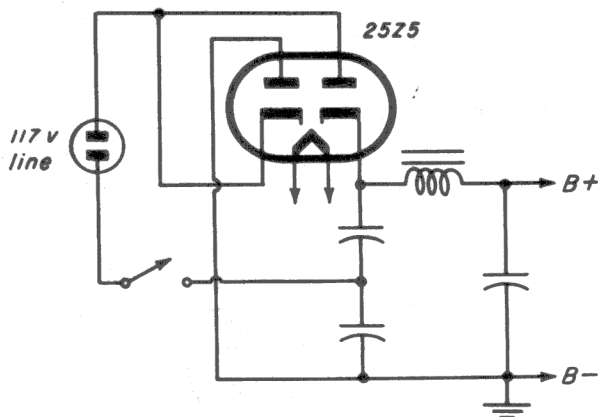
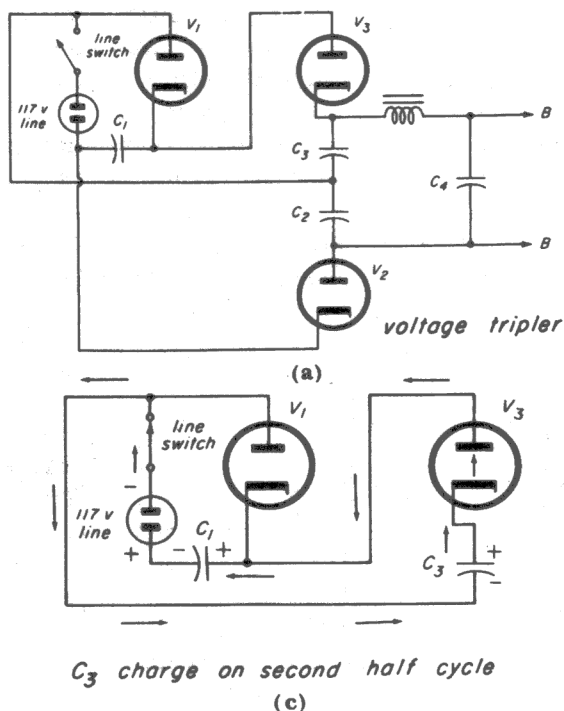


Fig. 21-19

know how the capacitors become charged. The charging circuit of C_1 is shown in Fig. 21-18b. It shows that the power line cycle is in the alternation that makes V_1 conduct. When the power line voltage changes its polarity and V_2 conducts (Fig. 21-18c), we find that the charge across C_1 and the power-line voltage are in series and add to each other. The voltage between the plate and cathode of V_2 is therefore the sum of the two voltages and the charge received by C_2 is approximately the same. Because the charge on C_2 is renewed once in every cycle, this is a half-wave doubler and the ripple frequency is the same as that of the power line. The voltage regulation of the half-wave voltage doubler is poorer than that of a full-wave voltage doubler.



Three tubes listed in your RCA Tube Manual are most often used in voltage-doubler circuits: the 25Z5, 25Z5-GT, and the 117Z6-GT. Figure 21-19 shows a circuit of a typical voltage doubler, using one of these tubes.

Voltage Tripler Circuits. Circuits that multiply the voltage three times are not very often used. The explanation that follows will show you that their action is much the same as that of a doubler circuit. For instance, Fig. 21-20a shows a typical voltage tripler circuit. In the first half cycle, V_1 and V_2 (Fig. 21-20b) conduct and charge C_1 and C_2 . During the second half cycle, V_3 conducts and (Fig. 21-20c) C_3 charges to a voltage that almost equals the sum of the charge on C_1 and the line voltage. So, if the charge on C_2 is considered to be E , then the charge on C_3 is $2E$. Because they are connected in series so that their charges add (Fig. 21-20d), the voltage across C_4 is $3E$ (less the drop in the choke). Capacitors C_3 and C_4 must have ratings that permit them to withstand the voltages that appear on them. The voltage regulation of a tripler circuit is poor. As a result, they are used only when the supply voltage and the load are constant. The ripple voltage of the multiplier has a frequency of twice that of the line voltage.

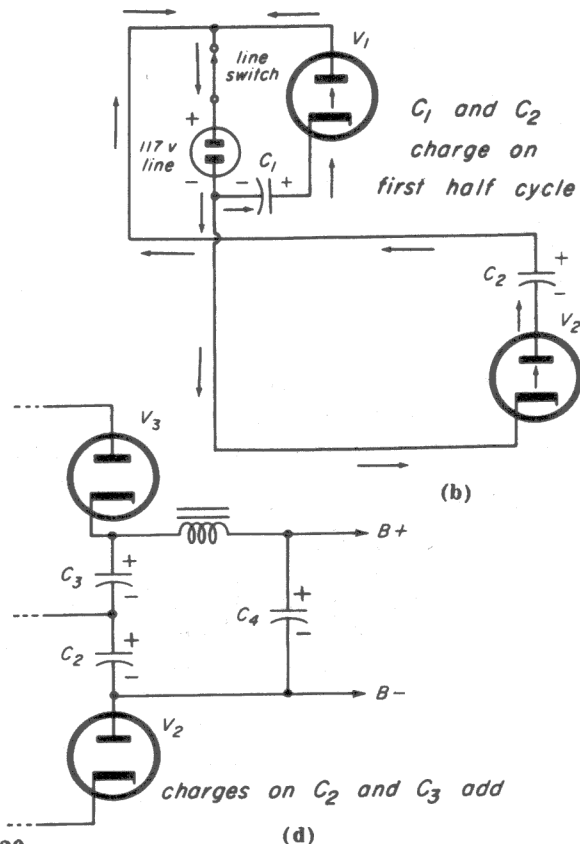


Fig. 21-20

Bleeder Current. A resistor, or several resistors in series, connected across a voltage will draw current. In the case of a voltage divider, even if the loads are disconnected, the divider itself will draw current. This is the bleeder current. It flows only through the divider, not through the loads.

We can choose the value of the bleeder resistor or the value of the voltage divider resistors to make the bleeder current light, such as the usual 5 to 10 percent of total current; or heavy, such as 25 percent or more, to improve voltage regulation of the supply (reduce variation of the d-c output level).

Figure 21-21a shows the filter and load circuits of a power supply. For example, suppose a power supply is to deliver 240 volts d.c. to a load that is expected to vary its current demand between 25 and 75 ma. Let us design first for low bleeder current; then design for a greater amount of bleeder current, and note the difference in regulation. First, let the bleeder current be 5 ma. Then the bleeder resistor (R_b) will be 48,000 ohms ($240/0.005$). The total load *maximum* current is 80 ma. Let us assume that the rectified voltage is 272 volts. For simplicity, let us assume that the total impedance of the power supply is the d-c resistance of the choke, L . In order to drop 32 volts (from 272 to 240) at 80 ma, the resistance of the choke should be 400 ohms ($32/0.08$). The load voltage across R_L is 240 volts.

If the load demand falls to 25 ma, the total *minimum* current is 30 ma. The voltage drop across the choke is 12 volts. The load voltage rises to 260 volts. The voltage regulation is:

$$\% \text{ Reg} = \frac{(260 - 240)}{240} \times 100 = 8.3\%$$

If better voltage regulation is desired, let us increase the bleeder current to 85 ma. Let the rectified voltage be the same, 272 volts. The bleeder resistor will be 2,824 ohms ($240/0.085$). The maximum total current is 160 ma. In order to drop 272 to 240 volts at 160 ma, the choke must have a d-c resistance of 200 ohms. If the load drops to 25 ma, the total current will be 110 ma. The voltage drop across the choke will be 22 volts. The load voltage will rise to 250 volts. The voltage regulation is:

$$\% \text{ Reg} = \frac{(250 - 240)}{240} \times 100 = 4.2\%$$

Thus, the voltage regulation can be improved by the use of greater bleeder current.

In Fig. 21-21b a voltage divider, with no load connected, is shown. The total resistance, R_t , between points X and Q is 20,000 ohms. By Ohm's law, $I_{R_t} = 0.012$ a, or 12 ma. This is the bleeder current. Note that the voltage drops E_{R_1} and E_{R_2} are each 120 volts. Now let a 10,000-ohm load, R_L , be connected across R_2 , as in Fig. 21-21c. The total effective resistance between points P and Q is now 5,000 ohms, and R_t is 15,000 ohms. The bleeder current flows through R_2 . The bleeder and load currents flow through R_1 . The bleeder current is no longer the same as in b. Since only one third of R_t is now between points P and Q, only one-third of the applied voltage, or 80 volts is across P and Q, or across R_2 . By Ohm's law, $I_{R_2} = 0.008$ a or 8 ma. Thus connecting or disconnecting loads changes bleeder current, as well as the voltage drops across the divider resistors. In general, bleeder current may be defined as the *difference* between the total current and the sum of the load currents.

21-4. AUTOMOBILE POWER SUPPLIES.

Mobile electronic equipment such as radio receivers and transmitters require power supplies that can provide the necessary A and B operating voltages. The voltage source for

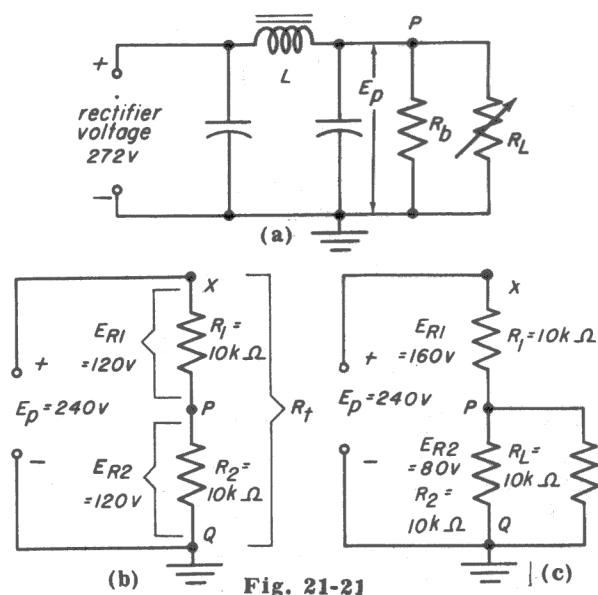


Fig. 21-21

such power supplies is usually a 6- or 12-volt storage battery. When auto radios first came out the *A* voltage was supplied by the car's battery and the *B* voltage came from *B* batteries made up from dry cells. This system was not very satisfactory, so engineers looked around for another method of providing power for auto radios. After many experiments they finally came up with a *vibrator*, a device that interrupted the d.c. from the car's 6-volt storage battery and transformed it into something like a.c. Such a vibrator, together with a cut-away view, is shown in Fig. 21-22. Let's look into this vibrator and see what makes it work.

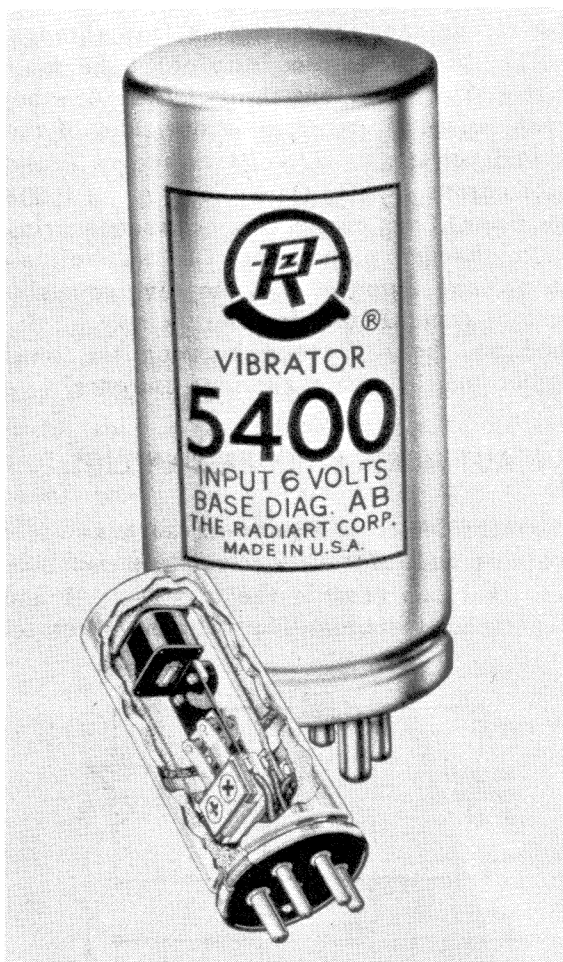


Fig. 21-22

The Vibrator. As we have said, the vibrator is a device that interrupts d.c. and changes it into something that acts like a.c. To understand the action of a vibrator, let's take the simple circuit shown in Fig. 21-23a. When the switch is closed, the voltage across *R* is instantly equal to the battery voltage and the

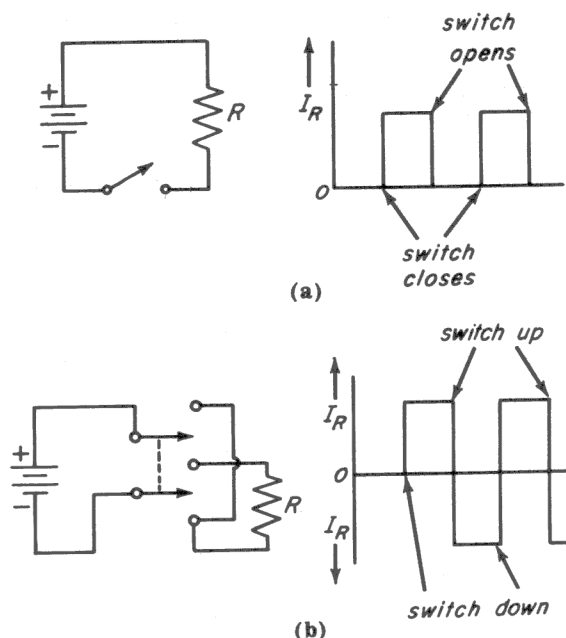


Fig. 21-23

current flowing through *R* rises instantly to its maximum value, as shown. When the switch is opened, the voltage is immediately removed from the resistor and the current drops immediately to zero. If the switch is alternately closed and opened, a pulsating d.c. will result. In this case current flows only during the periods when the switch is closed.

Now look at Fig. 21-23b. Suppose the switch is thrown in the up position, the current will flow as shown in the graph. Then if the switch is swung to the lower two contacts, the current through the resistor will change direction. If the switch is alternated back and forth, the current wave will look something like the graph in the figure. If the switch alternates 120 times a second, the current will go through 60 square-wave cycles a second. As you can see, it is not difficult to change d.c. into a.c.

Let's try somewhat the same thing with a transformer, such as that in Fig. 21-24.

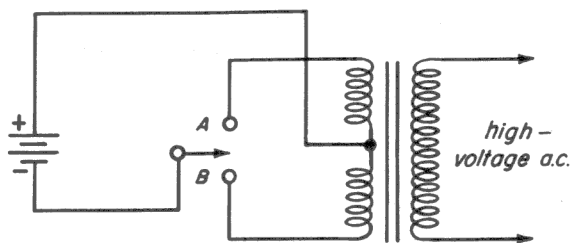


Fig. 21-24

This transformer differs from those you have seen in that it has two primary windings, each with the same number of turns, joined together as shown. The secondary has more turns than either primary winding so the transformer is a voltage-step-up transformer. Using such a transformer simplifies the switching arrangement when we want to reverse the battery connections to the primary. If the switch is alternated back and forth between terminals *A* and *B*, the input voltage to the transformer primary will change direction with each alternation, which will induce a.c. in the secondary.

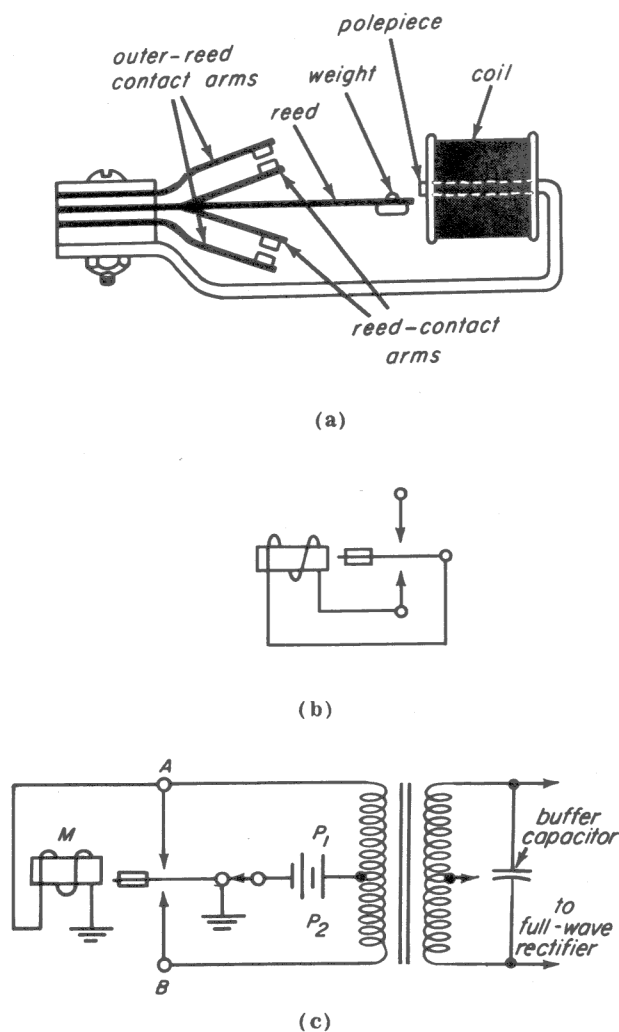


Fig. 21-25

Look at Fig. 21-25a. It shows the working parts of a vibrator. Fig. 21-25b shows the schematic symbol for the vibrator. When no current flows in the coil, the reed and reed-contact arms rest between the outer reed contact arms without making contact with either

outer arm. When current flows through the coil *M*, the weighted end of the reed is pulled upward and in line with the pole piece of the coil. This closes the circuit at *A*, which causes current to flow through the P_1 primary winding and at the same time, shorts out the magnetic coil of the vibrator. This causes the coil to lose its magnetism, which releases the reed, which springs back toward its normal resting position. However, the reed springs past the position of rest and closes the circuit at *B*. This causes current to flow in the primary winding, P_2 . However, when the reed moved away from *A* toward *B*, it removed the short across the coil, which now is magnetized again and attracts the weighted end back toward *A*. In this manner, so long as the vibrator coil is connected to the battery, the reed will vibrate back and forth and cause an a-c current of 115 cps to flow in the primary windings and cause a step-up voltage to be induced in the secondary. The 115-cycle rate is used instead of the 60-cycle rate of the standard power line, because inductive reactance rises with frequency; therefore power transformers made for this higher frequency need fewer turns of wire to offer the same impedance to the power line and rectifier as a transformer made for 60-cycle operation.

Look again at Fig. 21-25c. Notice that a capacitor is connected across the high-voltage secondary. This capacitor is called the *buffer capacitor* and is very important in the operation of a vibrator. To understand why this is so, let us go back to some theory that you learned when you studied about inductance. It was then that you learned that inductance is the property of a circuit that opposes a change in current in the circuit. When a single pulse of d.c. is applied to an inductor, as by closing and then opening the circuit, shown in Fig. 21-26, a magnetic field is built up around the inductor, which

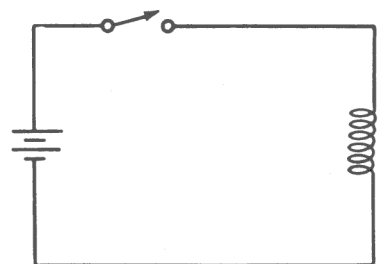


Fig. 21-26

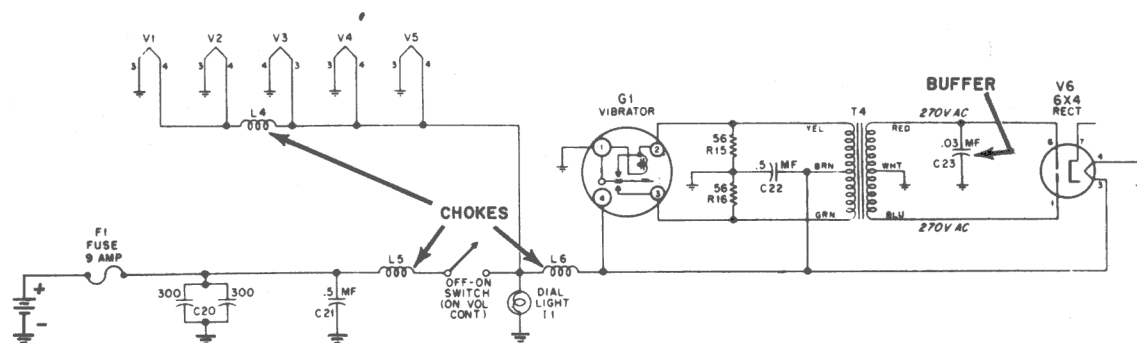


Fig. 21-27

collapses when the circuit is broken by opening a switch. The resistance of the circuit when the switch is closed is very, very little and so a high current flows. When the switch opens the resistance of the circuit becomes very, very high (practically infinite) yet the collapsing field tends to keep current flowing in the same amount as when the switch was closed. This causes a very high voltage pulse sometimes called an *inductive kick*, to be induced in the coil. You experimented with this inductive kick in Experiment Lesson 14, when you applied $4\frac{1}{2}$ volts to a choke and then opened the circuit, thus causing a neon bulb to ignite. When such a voltage pulse is found in a vibrator and transformer circuit, it may reach a potential of 1,000 volts or more, causing arcing between the vibrator contacts, and soon destroy them. By placing a capacitor across either the primary or the secondary, we reduce the effect of the inductive kick greatly without affecting the transformer action. When the switch is closed, the voltage across the capacitor has the same value and same polarity. When the switch is opened, the inductive voltage pulse caused by the collapsing field is of opposite polarity. So, the voltage produced by the collapsing field must reverse the charge of the capacitor, which tends to use up the energy being fed back. As a result, the voltage produced by the collapsing field never reaches a dangerous value.

It is better to place the buffer capacitor across the secondary winding than across the primary winding. In some cases it is placed in shunt with only one half of the high-voltage secondary, as in Fig. 21-27. The figure shows a schematic of a typical automobile-radio power supply. As you can see, the secondary winding connections are the same as for any full wave

rectifier. The circuit shown uses a heater-type rectifier. Other auto radios may use the same type of rectifier or a cold-cathode gas rectifier, which requires no heater voltage, but may require special filtering to remove noise that is due to the rectifier. Naturally, the heaters of the receiver tubes are connected to the auto's storage battery.

Notice the high-frequency chokes marked L_4 , L_5 , and L_6 in Fig. 21-27. These chokes are placed in the circuit to prevent *hash* (electrical noises from the vibrator or the automobile generator or ignition system) from reaching the other electrodes of the receiver tubes. The fuse is placed in the circuit to prevent overloading the battery, should a short circuit or an unusually heavy load appear in the receiver.

The type of vibrator that we have been discussing is called a *non-synchronous* vibrator because it produces only alternating pulses to operate the power transformer. Another type of vibrator is called a *synchronous* vibrator. It not only supplies the primary voltage of the power transformer, it also rectifies the voltage that appears across the high-voltage secondary. A synchronous vibrator is very much like a non-synchronous vibrator, except for the fact that it has two sets of points. The electrical circuit for such a vibrator is shown in Fig. 21-28. Notice that the polarity of the primary and

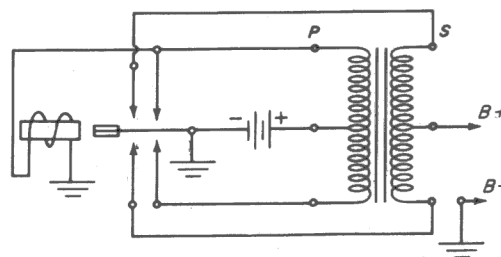


Fig. 21-28

secondary connections is such that the common tap of the primary winding and the center tap of the secondary winding is positive.

As you have seen in your study of the non-synchronous vibrator, the vibrator acts as a switch to produce alternating pulses of d.c. to supply the transformer primary windings. The job of the synchronous vibrator is to do the same thing and, to go one step further, to change the secondary voltage into d-c pulses that all have the same direction. This, too, is done by switching action, and the synchronous vibrator is so called because the rectification action is synchronized in step with the voltage pulses that are fed to the primary windings.

Let's see how a synchronous vibrator works. Fig. 21-29a shows the vibrator in position A, where it makes contact with the upper primary winding P_1 and the upper half of the high-voltage secondary. The current that flows in P_1 induces a voltage in secondary S_1 , and the negative end of S_1 is switched to ground through the S_1 contacts of the vibrator. The positive end goes to the high-voltage center tap, as we noted before. Then the vibrator reed springs over to position B, and current flows through P_2 , which

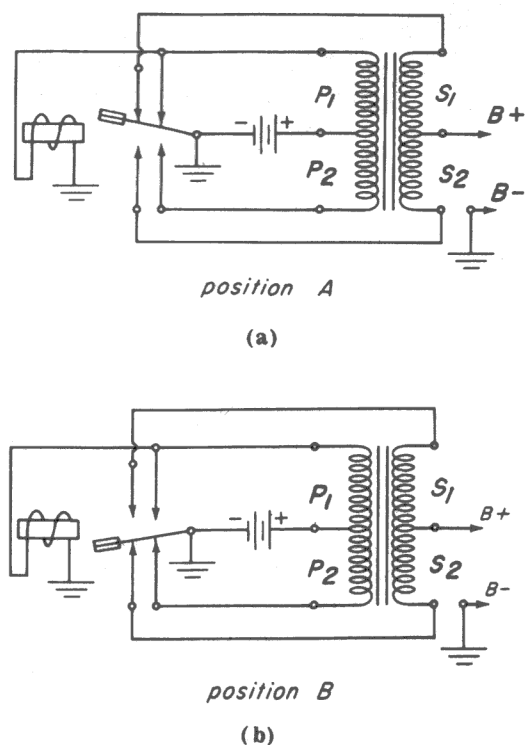


Fig. 21-29

induces a voltage in the secondary S_2 . At the same time, the negative end of the winding is returned to ground through the S_2 contacts of the vibrator and the positive end is at the center tap of the high-voltage winding. Fig. 21-29b shows that this switching action of the vibrator produces d-c pulses. This pulsating d.c. is filtered, as in other full-wave rectifier circuits and the filtered output provides B voltage for the auto radio.

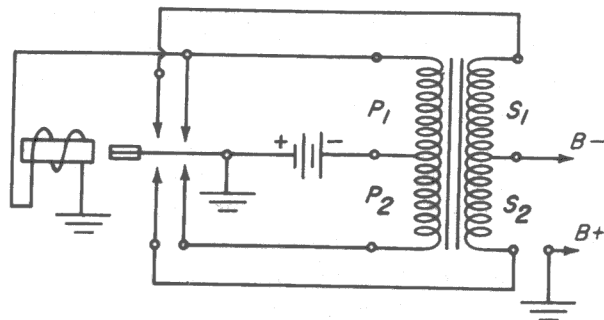


Fig. 21-30

A synchronous-vibrator power supply needs no electron-tube rectifier so it takes up less room. The synchronous vibrator is not as popular as the non-synchronous type. One reason for this is that not all cars are wired so that the negative side of the battery is grounded; in some cases the positive side is grounded. Yet when auto sets are manufactured they are usually wired with the negative side going to ground. If such a set is installed in a car that is positively grounded, the output voltage of the rectifier has reversed polarity (see Fig. 21-30). No set can operate with $B-$ going to the plates of the tubes, so it is necessary to check the polarity of the car wiring and to see that the receiver has the same polarity. This is usually done by switching one or two connections at the power supply or by reversing the position of the vibrator in its socket.

21-5. POWER CONVERTERS AND GENERATORS.

Most radio, phono, and television equipment manufactured in this country is made for operation on 110 - 120-volts, 60-cycle a.c. When the local electric power is not suitable, or where batteries cannot directly supply the power we need, a power converter or one of several types of generators may serve

our needs. It pays to know something about the different types that are available. Such power equipment is normally purchased as a unit and not designed and made by the serviceman.

Vibrator-Type Converters. Power converters that make use of vibrators, similar to those used in auto radios, are made to operate on 6, 12, 28, and 110 volts d.c. The output of such a converter is either 110 or 220 volts, 60-cycle a.c. Vibrator converters are made to power radio or television receivers, phono-players, electric shavers, dictating machines, and similar equipment. The advantage of such converters is that no wiring changes are necessary to operate the equipment. All that is needed is to connect the converter to the proper power source and plug the equipment into the output of the converter. A typical vibrator converter is shown in Fig. 21-31.

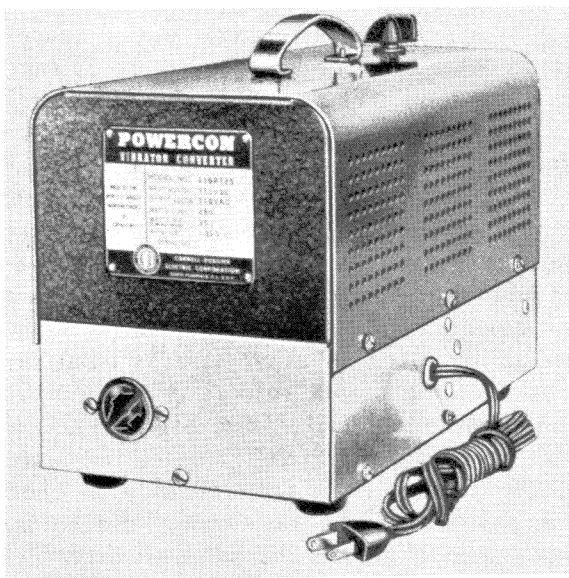


Fig. 21-31

Rotary Converters. Another type of power converter is the *rotary* type. They are made to operate on an input of 6, 12, 24, 28, 32, 64, 115, and 230 volts d.c. with a 60 cycle 115-volt output. A rotary converter (Fig. 21-32) consists of a d-c motor and an a-c generator with a common rotating shaft. Like the vibrator-type converter, the rotary converter require no wiring changes in the equipment it powers.

Engine-Driven Generators. Sometimes a receiver, transmitter, or some public-address

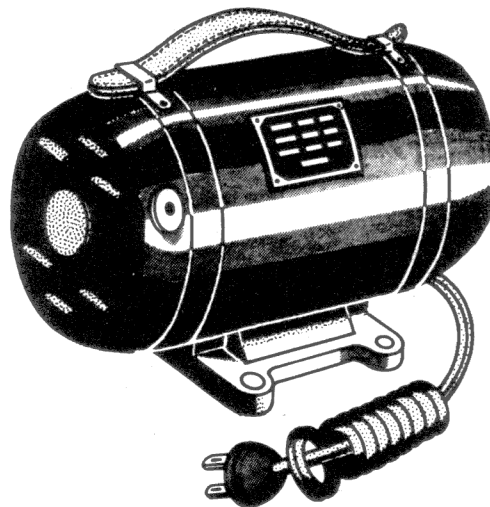


Fig. 21-32

equipment may be powered by a generator driven by a gasoline engine. Most are designed to deliver 110-volt 60-cycle a.c. It is usual to provide d.c. to excite the generator field. This may come from the 6- or 12-volt auto or truck battery, if the equipment is mobile, or from a separate storage battery.

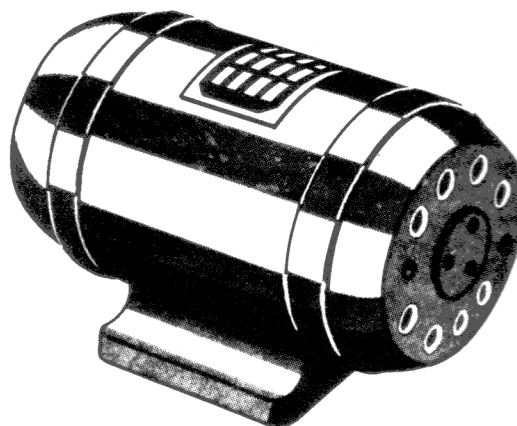


Fig. 21-33

Dynamotors. A dynamotor (Fig. 21-33) is a motor generator that is made to supply plate, screen, and grid voltages for portable and mobile radio receivers and transmitters. A dynamotor differs from most motor generators in that both the motor and the generator armature coils are wound on the same core and turn in the same field. They are designed to operate on 6, 12, or 24 volts of d.c. (usually from batteries). Standard dynamotors are made to supply B voltages as high as 500 volts. Many are supplied with built-in filters so that no further filter is necessary to provide d-c power for electron-tube circuits.